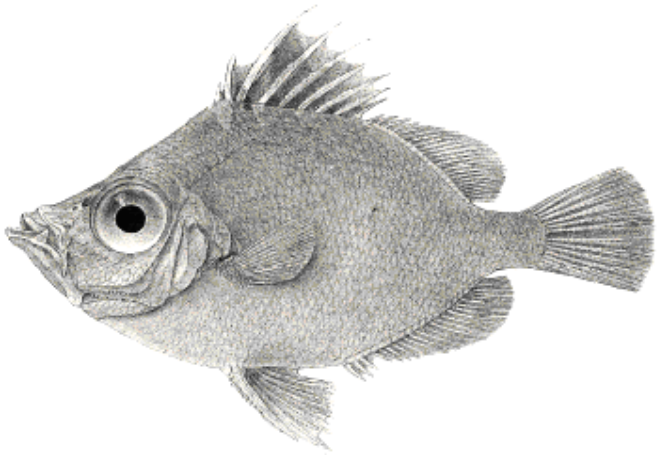
FEAS Survey Series: 2013/03

Boarfish Acoustic Survey
Cruise Report

10 July – 31 July, 2013



Day (1966)

MFV Felucca

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1 Introduction

From the early 1970s the abundance of boarfish (*Capros aper*) was seen to increase exponentially and distribution spread increasingly northwards along the western seaboard and Bay of Biscay (Blanchard and Vandermeirsch, 2005). At the same time, boarfish were caught in increasing quantities in both pelagic and demersal fisheries. This in turn resulted in damage to more commercially valuable target species. Exploratory fishing for boarfish by Irish vessels began in the later 1980s when commercial quantities were encountered during the spring horse mackerel (*Trachurus* trachurus) and mackerel (*Scrombrus scomber*) fishery in northern Biscay. Several landings were made into Ireland for fishmeal during this time but due to logistical problems related to handling (prominent dorsal spines) this species was not favoured by processors. Interest increased again around the mid 1990s when Dutch pelagic vessels landed frozen samples to determine if a market could be developed for human consumption.

During the early 2000s the Irish landings were relatively small (<700t per yr) and it was not until 2006 that a directed fishery developed. Fishing was undertaken primarily by vessels from the Castletownbere and Killybegs based RSW fleets (refrigerated seawater vessels), which targeted boarfish from northern Biscay to the southern Celtic Sea. In 2007-08 vessels from Scotland and Denmark also began targeting boarfish in quantity. Irish landings are primarily landed into fishmeal plants in Denmark and the Faroe Islands with increasing amounts being landed in Killybegs in recent years. The boarfish fishery bridged an important gap between the short season fisheries for horse mackerel, mackerel and blue whiting (*Micromesistius poutassou*) affectively extending the fishing season for the RSW fleet.

A precautionary interim management plan was adopted in November 2010 covering ICES Divisions VI, VII and VIII and an EU TAC of 33,000t was set. Of this the Irish allocation for 2011 was 22,000t. This precautionary TAC was based on 50-75% of total landings from the period 2007-2009 which peaked at over 83,400t (2009). Landings in 2010 reached over 137,000t prior to the introduction of TAC control. In addition to the TAC, seasonal closures were implemented; from September 1- October 31 (Division VIIg) to protect herring feeding and pre spawning aggregations and from March 15–August 31 where mackerel are frequently encountered as a large bycatch. A catch rule ceiling of 5% bycatch was also implemented within the fishery where boarfish are taken with other TAC controlled species. In 2013 the EU TAC was set at 82,000t with an Irish allocation of 56,666t, a roll over from 2012.

This survey represents the third dedicated research survey for boarfish in the time series. The commercial fishing vessel MFV *Felucca* (as in 2011), an active participant in the fishery, was equipped with a calibrated scientific echosounder (Simrad EK 60) and transducer within a towed body.

Data from this survey, in addition to the extensive biological research carried out on this species, forms part of a larger program aimed at increasing the knowledge of this species and its abundance outside of the commercial fishery. Data from this survey will be presented for inclusion into the ICES Planning Group meeting for International Pelagic Surveys in January 2014 (WGIPS) and for the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) meeting in August 2013.

2 Materials and Methods

2.1 Scientific Personnel

Organisation	Name	Capacity
FEAS	Ciaran O'Donnell	Acoustics (SIC)
KFO	Edward Farrel	Biologist
FEAS	Eoghan Kelly	Biologist
Contractor	Francis McDaid	Fisheries Obs

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives of the survey are listed below:

- Collect integrated and calibrated acoustic data on boarfish (*Capros aper*) aggregations within the pre-determined survey area
- Determine the biomass and abundance of boarfish within the survey area
- Collect biological samples from directed trawling on insonified echotraces to determine age structure and maturity state of survey stock as well as to identify echotrace to species.
- Determine the extent and behaviour of boarfish aggregations within the survey area to aid the design of future surveys
- Dovetail with the RV Celtic Explorer in the northern area to ensure close spatio-temporal alignment and synoptic coverage

2.2.2 Area of operation and survey design

The survey started in the Porcupine Bank area before moving to survey the shelf area between 53°30N and 47°30N from north to south following a pre-determined cruise plan (Figure 1). Area coverage was based on the distribution of catches from the IBTS survey time series, catch data and from the previous survey (O'Donnell *et al* 2012.Timing was planned to coincide with the arrival of the RV *Celtic Explorer* in the northern survey area to ensure a continuous, quasi-synoptic coverage of the combined area.

In total 4,295nmi (nautical miles) of cruise track was undertaken by both vessels over 53 transects relating to a total area coverage of 57,020nmi². Transect spacing was set at 15nmi for the *Felucca* and 15 and 7.5nmi for the *Explorer* component. For the area covered by the *Explorer* only strata bordering the shelf edge were considered during the analysis.

Coverage extended in coastal areas from the c.50m contour to the shelf slope (250m). An elementary distance sampling unit (EDSU) of 1nmi was used during the analysis of combined survey data.

The survey was carried out from 04:00–00:00 each day for both surveys to coincide with the hours of daylight when boarfish are most often observed in homogenous schools. During the hours of darkness boarfish schools tend to disperse into mixed species scattering layers.

2.3 Sampling protocols and equipment specifications

2.3.1 Acoustic equipment

Equipment settings were determined before the start of the survey and are based on established settings employed on previous surveys (O'Donnell *et al.,* 2004 & 2011).

Acoustic data were collected using a Simrad EK 60 scientific echosounder topside unit. A Simrad ES-38B (38 KHz) split-beam transducer was mounted within a towbody frame and deployed on the port side via a towing boom to a working depth of 3-3.5m (Appendix 1).

Cruising speed was largely determined by the weather and the affects on the quality of acoustic data. Where possible cruising speed was maintained at 10kts.

2.3.2 Calibration of acoustic equipment

The EK 60 was calibrated offshore on route to the Porcupine Bank and the survey start point on the 10 July in calm conditions. The calibration was carried out using standard methodology as described by Foote *et al.* (1987). Results of the calibration are presented in Table 1.

2.3.4 Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing unit. The "RAW files" were logged via a continuous Ethernet connection as "EK5" files to a laptop and a HDD hard drive as a backup. Sonar Data's Myriax Echoview® Live viewer (Version 5.0) was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of target schools to a log file. A member of the scientific crew monitored the equipment continually. Time and location were recorded for each transect start/end position within each stratum. This log was also used to monitor "off track events" such as fishing operations.

2.3.5 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Echoview. The scrutiny process involved the allocation of echotraces (schools) to particular species or species mix categories, based on the information from the directed trawl hauls.

The NASC (Nautical Area Scattering Coefficient) values from each boarfish echotrace were allocated to one of 4 categories after scrutiny of the echograms. Categories identified on the basis of echotrace scrutiny were as follows:

1. "Definitely boarfish" echotraces were identified on the basis of captures of boarfish from the fishing trawls which were sampled directly. Based on the directly sampled schools we also characterised echotrace as definitely boarfish which appeared very similar on the echogram i.e. , large marks which showed as very high intensity (red), located high in the water column (day) and as strong circular schools.

2. "Probably boarfish" were attributed to smaller echotraces that had not been fished but which had similar characteristics to "definite" boarfish traces.

3. "Boarfish in a mixture" were attributed to NASC values arising from all fish traces in which boarfish were contained, based on the presence of a proportion of boarfish in the catch or within the nearest trawl haul. Boarfish were often taken during trawling in mixed species layers during the hours of darkness.

4. "Possibly boarfish" were attributed to small echotraces outside areas where fishing was carried out, but which had the characteristics of definite boarfish traces.

This set of categories allowed us to present the biomass estimates in terms of the best estimate (Cats 1-3), the minimum estimate (Cat 1 + 3), and the maximum estimate (Cats 1-4).

Echograms were divided into transects and off track events, including trawl hauls and hydrographic stations were excluded. Echo integration was performed on regions which were

defined by enclosing selected parts of the echogram that corresponded to one of the four categories above. The echograms were generally analysed and echo-integrals calculated, at a threshold of -70 dB, where necessary heavy backscatter from plankton was filtered out by thresholding at –65 dB.

2.3.6 Biological sampling

A single pelagic midwater trawl with the dimensions of 296m in total length with a 78m brailer was used during the survey. The horizontal net spread was averaged 90m from wing to wing. Mesh size in the wings was 12.8m through to 2cm in the cod-end liner. The net was fished with a vertical mouth opening averaging 50m, which was observed using a cable linked Simrad FS 900 netsonde (200 kHz). The net was fitted with Marport catch and tunnel sensors to monitor the amount catch entering the trawl.

All components of the catch were sorted to species and weight by species. For species other than boarfish, length and weight measurements were taken for 100 individuals per trawl in addition to a c.300 fish length frequency sample. Length, weight, sex and maturity data were recorded for individual boarfish in a random 50 fish sample from each trawl haul. In addition a further 100 length/weight and 300 fish length frequency measurements were taken from each haul. Due to the complexity of aging boarfish, no aging was carried out onboard and samples were analysed back in the lab. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

The decision to fish on particular echotraces was based on both the distance from other fishing operations on similar schools, and on the difference between recently observed echotraces and others previously sampled.

2.4 Analysis methods

2.4.1 Abundance estimates

The recordings of area back scattering strength (NASC) per nautical mile were averaged over a one nautical mile EDSU (Elementary sampling distance unit), and the allocation of NASC values to boarfish and other acoustic targets was based on the composition of the trawl catches and the appearance of the echotraces.

To estimate the abundance, the allocated NASC values were averaged for ICES statistical rectangles (1° latitude by 2° longitude). For each statistical area, the unit area density of fish (S_A) in number per square nautical mile ($N*nmi^{-2}$) was calculated using standard equations (Foote et al. 1987, Toresen *et al*. 1998).

NASC values assigned according to scrutinisation methods (section 2.3.5) were used to estimate the boarfish numbers according to the method of Dalen and Nakken (1983).

The following TS-length relationships used were those recommended by the acoustic survey planning group (ICES, 1994):

Herring	TS = $20\log_{10}L$ – 71.2 dB per individual (L = length in cm)
Sprat	TS = $20\log_{10}L$ – 71.2 dB per individual (L = length in cm)
Mackerel	TS = $20\log_{10}L$ – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = $20\log_{10}L$ – 67.5 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS = $20\log_{10}L$ – 67.4 dB per individual (L = length in cm)

For boarfish (*Capros aper*) a species specific TS length relationship was applied based on theoretical swimbladder modelling (Fassler *et al.* 2013).

Boarfish $TS = 20\log_{10}L - 66.2$ dB per individual (L = length in cm)

To estimate the total abundance of fish, the unit area abundance for each statistical rectangle was multiplied by the number of square nautical miles in each statistical square and then summed for all statistical rectangles for the total area. Biomass estimation was calculated by multiplying abundance in numbers by the average weight of the fish in each statistical rectangle and then sum of all squares by rectangle and summed for the total area.

3 Results

3.1 Boarfish abundance and distribution

The results presented here are a composite of data collected during this survey and on the northwest herring survey (RV *Celtic Explorer*). Surveys were timed to ensure a continuous, quasi-synoptic, coverage that took 41 days without interruption from north (58°30N) to south (47°30N). Both surveys used calibrated echosounders and an inter-vessel acoustic calibration exercise was carried out (results pending).

Thirty three hauls (*Felucca: 31; Explorer*: 2) were carried out during the survey, 19 of which contained boarfish (Figure 1, Table 2). In total, 4,753 lengths and 1,852 length/weight measurements were taken in addition to 799 individual boarfish otiliths collected for aging.

3.1.2 Boarfish biomass and abundance

A full breakdown of the stock estimate is presented by strata, age, length, maturity, biomass, abundance in Tables 4-8 and Figures 3 & 4.

Boarfish	Abund (mils)	Biomass (t)	% contribution
Total estimate			
Definitely	8,834	431,571	98.1
Probably	240	7,187	1.6
Mixture	17	1,139	0.3
Total estimate	**9,091**	**439,897**	**100**
Possibly	-	-	
SSB Estimate			
Definelty	8,120	416,124	98.3
Probably	179	5,895	1.4
Mixture	17	1,139	0.3
SSB estimate	**8,316**	**423,158**	**100**
Possibly	-	-	

3.1.3 Boarfish distribution

A total of 1,074 boarfish echotraces were identified during the survey. Of this 98% were categorised as 'definitely' boarfish, 1.6% as 'probably' and 0.3% 'boarfish in a mixture'. A full breakdown of school categorisation, abundance and biomass by ICES statistical rectangle is provided in Table 9. A total of 63 ICES rectangles were covered by the survey representing combined area coverage of 57,020nmi² an increase of 11% from 2012.

The southern area contained the largest proportion of stock biomass (64%). The second most abundant area was the western area where 21% of biomass was recorded. The northern area and Porcupine Bank contributed 3% and 12% respectively. The proportion of the stock biomass within each area is similar to that observed in 2011-2012.

On the Porcupine Bank, boarfish were observed in a cluster of medium to high density echotraces located close to the shelf edge (Figure 2 & Figure 5a). Echotraces were more numerous and of higher acoustic density than previous years, contributing 12% to the total stock biomass (54,200t) and 9% total abundance (783.1 million). Boarfish samples from this area were composed of mature (>5 yrs old) actively spawning individuals. Area coverage totalled 7,298nmi² and was comparable to previous years.

The northern area contributed 3% (13,900t) to the total biomass and 2% (211.4 million) to total abundance. Echotraces in this area were low in number and of low acoustic density overall (Figure 5b). Geographical distribution was comparable to previous surveys, as was

acoustic density and biomass. Boarfish samples were composed of mature, spawning fish. Area coverage totalled 9,366nmi² and was comparable to previous years.

The western area contributed 21% (92,700t) to total biomass and 17% (1509.4 million) to total abundance. This area was characterised by clusters of medium and high density echotraces and single smaller low density echotraces (Figure 5c). The distribution of the highest density echotraces occurred from 160-180m as compared to 2011-2012 where high density aggregations were observed from 70 to 180m. However, this maybe related to water temperature rather than depth. Echotraces were primarily located midwater below the thermocline (c.60m) and were actively spawning. Overall the number and acoustic density of boarfish echotraces within the western area was lower than in 2012. Area coverage totalled 11,859nmi² and the area surveyed was slightly larger than 2012 due to the extension of transects further west off the shelf edge (500m).

The southern area contributed 64% (279,200t) to total biomass and 73% (6587.1.4 million) to total abundance. Within this area 3 sub areas were identified from previous surveys. The first, located off the southwest coast contained spawning fish close to the shelf edge and further to the east around a number of offshore Banks. This sub area is commonly associated with over wintering aggregations. Abundance within this area was low as in previous years. The second area was located in the east around a complex of offshore banks and was found to contain feeding aggregations of resting mature and immature boarfish. Clusters of high density echotraces were found within a localised area and were actively feeding within the surface layer above the thermocline (Figure 5d). The third sub area extended from 49°N to 47°30N along the shelf edge. This area is characterised by a series of deep canyons and has consistently produced the highest abundance of boarfish during the survey. High density echotraces of spawning boarfish were located close to the seabed within this sub area (Figure 5e).

3.1.4 Boarfish stock structure

An age length key compiled primarily from commercial samples collected during 2012/2013 fishery was applied during the analysis of survey data. This ALK was used in place of a survey derived ALK due to the unavailability of aged samples during the analysis

Age distribution as determined from survey samples indicate that the stock is dominated by the following age classes in terms of abundance: 3, 15+, 7 and 8 year old fish and 15+, 7, 8 and 9 years in terms of biomass (Figure 3, Table 5 & 6).

The north, west and Porcupine Bank were made up of almost exclusively mature fish. Immature (< 9.7 cm TL) boarfish were observed in the highest abundance in the southern area accounting for 3.8% of TSB and 8.5% of TSN and were located on shelf in an area of Banks south of 50°N (Table 7 & 8, Figures 2 & 4). Immature and resting mature individuals were found actively feeding in this area. The abundance of immature fish in 2013 was the highest observed to date.

3.2 Other pelagics

3.2.1 Herring

In total 100 herring (*Clupea harengus*) echotraces were observed during the survey and 5 trawl samples yielded herring (Table 2). The distribution of herring was divided into two distinct areas; west of the Aran Islands and southwest of Ireland. The largest single herring echotrace was observed southwest of Mizen Head and would form part of the autumn spawning component of the Celtic Sea stock. The west of the Aran Islands, herring feeding aggregations were observed and these fish are most likely to spawn in or around the North Sound of Galway Bay in autumn (Figure 5f). No biomass or abundance calculation was made for this species.

A total of 224 herring were measured and 194 length and weights were recorded. The modal length of herring was 26.5cm (range 16.5-34.5cm) and mean weight was 159g.

3.2.2 Horse mackerel

Horse mackerel (*Trachurus trachurus*) were encountered in 35% of survey hauls and were most frequently encountered in deeper waters (>80m) and often occurred in catches with boarfish (Table 2).

A total of 594 horse mackerel were measured and 210 length and weights were recorded. The modal length of horse mackerel was 29.4cm (range 16-39cm) and mean weight was 221g.

Horse mackerel were widely distributed throughout the survey area from the Porcupine Bank to the southern Celtic Sea occurring mainly as medium density echotraces spaced over a wide area. In total 442 echotraces were assigned to horse mackerel during the survey. No biomass or abundance calculation was made for this species.

As in previous years stomach contents analysis revealed horse mackerel to be actively feeding on boarfish eggs where the two species were encountered together.

3.2.3 Blue whiting

Blue whiting (*Mircomesistius poutassou*) were encountered in 13% of trawls. No calculation of biomass was determined from survey data at this time.

A total of 763 blue whiting were measured and 300 length and weights were recorded. The modal length occurred at 19cm (range 13-27cm) and mean weight was 50g.

Blue whiting were found widely distributed along the shelf edge as mature fish (>3 yrs) and as juveniles on-shelf. Large high density schools of mature fish were observed along the offshore inter-transects south of 51°N. High density on-shelf schools of 1-group immature fish were observed from 53°N southwards as observed during previous surveys (Figure 5h).

3.3 Hydrographic conditions

Calibrated hydrographic data was collected during the tri-annual mackerel egg survey which covered the same geographical area as boarfish survey from July 13- August 02 onboard the Celtic Explorer. The survey worked from south to north in opposition to the boarfish survey. A total of 97 casts were made and compiled to produce horizontal plots of conditions from 5m to 100m (Figures 7-10).

Overall, sea surface temperatures were high and were exacerbated by a 2 week period where air temperatures reached over 26°C in the middle of the survey (Figure 7). The thermocline was observed at between 45-60m and water temp at 20m depth average 14-15°C north of 49°N and 16-17°C for latitudes south. Cooler waters dominated southwest and south coastal waters at 20m (Figure 8). At a depth of 50m (on or below the thermocline) the extent of cooler water (<13°C) is more evident along the west coast and extends right across the Celtic Sea shelf sea. Overlaying boarfish NASC values onto the temperature data for 50m and 100m depth profiles reveals a link between temperature and distribution (Figures 9 & 10). Boarfish are clearly distributed in the 12-14°C frontal area.

4 Discussion and conclusions

4.1 Discussion

Overall, the survey can be considered a success with all components of the work program completed as planned with no unforeseen downtime. Survey design, timing, transect spacing and geographical coverage were maintained from 2012. Area coverage increased by 11% compared to 2012 with extension into the eastern Celtic Sea and to a lesser extent in the west off the shelf edge.

The total number of echotraces detected in 2013 was comparable to 2012 (6% lower), however, acoustic density of these echotraces was much reduced. The single largest boarfish NASC in 2013 was 75% less than the largest observed in the previous year. Echotrace identification was considered accurate with over 98% of the total biomass attributed to the def category. The ability to scrutinise echotraces to this degree was achieved through comprehensive trawl sampling.

Overall, the total stock biomass was down by 46% (33% reduction in abundance) than at the same time in 2012. The percentage contribution of biomass across the four surveys areas was comparable, with the south and west ranking highest followed by the Porcupine Bank and northern area (C Explorer) respectively. However, acoustic density was much lower as was individual school size and clustered spawning aggregations. Along track sonar observations made during the survey support echosounder observations in that school density was lower and more scattered.

Boarfish spawning behaviour in terms of school positioning in the water column followed the same pattern as observed previously; fish in the north and west and Porcupine Bank maintained a position higher in the water column just below the thermocline, whereas those in the Celtic Sea were generally closer to the seabed.

Boarfish distribution over the entire survey area when overlaid with temperature data at 50m and 100m showed a defined thermal preference within a 12-14°C frontal boundary. This was evident both for spawning aggregations in the north and south as well as for juvenile aggregations in the southeast. In the western area preferred spawning habitat may have been constricted by the dominance of cooler water on–shelf (<12°C) pushing spawning aggregations further west towards deeper, warmer water. Detailed hydrographic data available in 2013 was not available in 2011 or 2012 to compare conditions during spawning.

The stock was considered to be well contained geographically within the survey area. Transects were extended to the west into deeper water (500m) and in the east to ensure coverage of the shelf. No boarfish were observed on the southern most transect of the survey (47°30N). The IFREMER PELGAS acoustic survey in the Bay of Biscay (May-June) reported no boarfish during the entire survey which supports our southern containment (Pierre Pettitgas *pers comm.*). Geographical overlap was again achieved but with a temporal gap of almost 2 months. Hydrographic conditions as reported by the PELGAS survey indicate that the water column was poorly stratified at that time (May) and that phytoplankton and zooplankton biomass was low as in 2012.

4.2 Conclusions

Acoustically derived estimates of abundance are used as a relative index of abundance of the stock present within the survey area at the time of surveying. The survey therefore acts as a 'snapshot' of the stock and should not be considered as a measure of absolute stock abundance. The use of an abundance index allows for the percentage change between successive estimates to be tracked over time to reveal trends in stock abundance as the time series develops.

Geographical coverage can now be considered as established for all core spawning areas covered during the survey. Southern containment, although achieved in 2013 remains a potential weak spot and continued adaptive coverage is a requirement.

Overall, the large change in biomass observed between years cannot be easily explained and is no doubt the result of multiple factors. Expected inter-annual variation between successive acoustic estimates is in part responsible. However, factors outside survey effects should also be considered including hydrographic conditions and prey availability. As boarfish continue to feed during spawning the availability of prey will also determine spatial distribution of schools locally and clusters of schools at larger scales. If conditions for spawning are not optimum then the prey availability will drive distribution.

As the survey covered the same area using the same survey design and good trawl sampling was achieved it is methodologically a replicate of that performed in 2012. However, factors outside of the survey have no doubt influenced the distribution of the stock both in the large scale (how it was distributed over the greater survey area) and at the smaller scale (in terms of schooling behaviour). The latter being directly related to how available boarfish were to the acoustic recording equipment. As no bottom trawl was available during the survey it was not possible to target the seabed within the acoustic dead zone (ADZ) for presence/absence of boarfish. Unquantified sonar observations and off track investigations indicated that echosounder observations were indeed representative of aggregations present in the wider area. This raises the possibility that boarfish could have also been distributed within the ADZ and out of the range of echosounder and midwater trawl sampling.

4.3 Recommendations

The following recommendations are based on observations made during the survey and are provided as a means of improving future surveys.

- The timing of the survey should continue to be aligned with the northwest herring survey to extend the area coverage in the northern area and ensure northern containment of the stock.
- Southern containment of the stock. All efforts should be made to ensure good containment of the stock in the southern region of the survey.
- Continued participation in the annual ICES WGACEGG meeting to facilitate acoustic data and knowledge exchange between participant countries surveying in the Celtic Sea and Bay of Biscay.

Acknowledgements

We would like to express our thanks and gratitude to Peter Mogan (Skipper) and crew of the FV *Felucca* for their good will and professionalism during the survey. The help and knowledge imparted during the survey was invaluable in helping to understand the behaviour of this species. Thanks also to Brendan O'Hea for providing the hydrographic data from the Mackerel Egg Survey (Ireland).

This survey is funded by a general levy on all vessels participating in the boarfish fishery. The analysis of these data is co funded by the Marine Institute, United Fish Industries Ltd. and the Killybegs Fishermens' Organisation Ltd.

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Table 1. Survey settings and calibration report (38kHz) for the tow body system (Simrad ER60 echosounder).

Echo Sounder System Calibration

Vessel :	F/V Felucca	Date :	10.07.13
Echo sounder :	EK60 Tow Body	Locality :	Offshore
Type of Sphere :	CU 64	TS_{Sphere}: -33.50 dB (Corrected for soundvelocity or t,S)	Depth(Sea floor) : 70 m

Calibration Version 2.1.0.12

Comments:
Offshore drift calibration. Weather conditions good

Reference Target:

TS	-33.52 dB	Min. Distance	13.0m
TS Deviation	5 dB	Max. Distance	16m

Transducer: ES38B Serial No.

Frequency	38000 Hz	Beamtype	Split
Gain	24.97 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.42 deg	Along. Beam Angle	7.27 deg
Athw. Offset Angle	0.28 deg	Along. Offset Angl	0.03 deg
SaCorrection	-0.61 dB	Depth	6.00 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.192 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
ER60 Version 2.2.1

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	8.2 dB/km	Sound Velocity	1500.3 m/s

Beam Model results:

Transducer Gain =	26.03 dB	SaCorrection =	-0.67 dB
Athw. Beam Angle =	7.00 deg	Along. Beam Angle =	7.03 deg
Athw. Offset Angle =	0.26 deg	Along. Offset Angle=	-0.10 deg

Data deviation from beam model:
RMS = 0.19 dB
Max = 0.87 dB No. = 364 Athw. = -3.4 deg Along = 2.5 deg
Min = -0.55 dB No. = 350 Athw. = 4.9 deg Along = -0.9 deg

Data deviation from polynomial model:
RMS = 0.14 dB
Max = 0.45 dB No. = 365 Athw. = 1.3 deg Along = -1.8 deg
Min = -0.39 dB No. = 180 Athw. = 2.9 deg Along = 2.2 deg

Comments :
Flat calm conditions
Wind Force : 5 kn. **Wind Direction :** E
Raw Data File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration 10.07.13
Calibration File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration 10.07.13

Calibration : Ciaran O'Donnell

Table 2. Catch composition and position of hauls undertaken by the MFV *Felucca* and for the Celtic Explorer.

Felucca

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Boarfish %	Mackerel %	Herring %	H Mack %	Others^ %
1	11.07.13	53.29	-14.23	10:51	235	150	5,000	95.4	0.7		3.9	
2	11.07.13	53.01	-13.20	16:27	246	200	60		21.0		79.0	
3	12.07.13	52.79	-14.34	06:10	355	150	2,000	14.3			85.0	0.7
4	13.07.13	53.51	-11.55	09:02	200	75	4,000	99.4			0.6	
5	13.07.13	53.28	-11.34	18:55	144	0	500		9.5	1.1	61.8	27.6
6	14.07.13	53.01	-11.69	07:12	160	60	2,500	98.1			1.9	
7	14.07.13	53.01	-10.90	11:19	134	40	2,000					100.0
8	14.07.13	52.76	-11.77	20:21	166	40-60	4,000	92.7	2.5		4.7	
9	15.07.13	52.00	-11.24	18:34	172	40-60	500	91.0	0.4		8.6	
10	16.07.13	51.50	-11.53	09:01	420	40-60	0					
11	16.07.13	51.51	-11.25	11:37	215	100-120	1,000	94.9	2.9		2.1	
12	17.07.13	51.02	-9.59	14:32	124	0-8	200		26.9	57.2		15.9
13	17.07.13	51.02	-11.05	20:58	185	0-8	2,000	98.8	1.2			
14	18.07.13	50.76	-9.12	11:43	123	0-6	10		6.7	73.3		20.0
15	18.07.13	50.76	-8.19	17:20	113	0-10	5,000			53.4	46.6	
16	19.07.11	50.51	-8.40	06:47	125	0-20	8,000		2.5		20.2	77.3
17	19.07.11	50.52	-10.17	14:18	157	0-25	200					100.0
18	19.07.11	50.57	-10.85	20:42	208	0-25	100					100.0
19	20.07.13	50.27	-9.32	11:28	135	0-10	100		1.8	1.6		96.6
20	20.07.13	50.27	-8.09	17:16	122	0-25	5,000		0.8			99.2
21	22.0.7.13	49.75	-8.74	09:18	114	50-80	10,000	100.0				
22	22.0.7.13	49.54	-7.94	16:53	144	20-65	8,000	100.0				
23	23.07.13	49.42	-11.37	12:28	340	41-313	200					100.0
24	23.07.13	49.27	-11.11	15:55	106	15-40	8,000	100.0				
25	24.07.13	49.04	-8.17	13:48	141	100	4,000	100.0				
26	25.07.13	48.77	-9.48	14:25	170	0-40	5,000	100.0				
27	26.07.13	48.51	-7.83	08:14	158	100	3,000	100.0				
28	26.07.13	48.53	-8.83	13:39	170	0-25	2,000	100.0				
29	27.07.13	48.28	-7.12	09:49	166	0-10	0					
30	27.07.13	48.26	-7.15	10:13	190	0-80	10,000	100.0				
31	30.07.13	52.79	-11.70	10:00	154	100	-	100.0				

^ Includes non target pelagic/demersal species and other taxa

Table 2. Continued

Celtic Explorer

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Boarfish %	Mackerel %	Herring %	H Mack %	Others^ %
9	01.07.13	56.52	-9.02	00:33	140	145	1,000	17.5	30.6	51.7		0.2
15	06.07.13	55.65	-8.96	23:00	85	100	500	46.5	1.4	52.0		0.1

^ Includes non target pelagic/demersal species and other taxa

Table 3. Age length key compiled from commercial catch and survey samples collected during 2011-2013.

Length	Age (years)														
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
6															
6.5															
7	1	1													
7.5	1	1													
8		1													
8.5		1	1												
9		1	1												
9.5			1												
10			1												
10.5			2	10	3										
11			1	29	14	2	2								
11.5				9	21	21	18	2	2	1					
12				4	17	22	38	12	8						1
12.5					5	9	42	37	14	6	2		1	1	1
13					2	4	31	28	24	12	6	2	3	1	5
13.5					1	3	25	22	21	14	6	5	4	2	11
14							6	8	18	22	8	3	7	1	20
14.5						1	1	2	3	8	1	6	6	6	30
15							1	1		2	2	2	5	2	19
15.5										2				2	19
16															8
16.5															1
17															1
17.5															
18															

Table 4. Boarfish length at age (years) as abundance (millions) and biomass (000's tonnes).

Length	Age (years)															Abundance	Biomass	Mn wt
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	(millions)	(000s t)	(g)
4.5																		
5																		
5.5																		
6																		
6.5																		
7																		
7.5																		
8		9.71														9.7	0.1	12.7
8.5																-	-	-
9		68.28	68.3													136.6	2.4	17.7
9.5			547.9													547.9	11.3	20.6
10			#####													1120.2	26.7	23.9
10.5			100.8	504.0	151.2											756.0	20.7	27.4
11			5.64	163.5	78.9	11.3	11.3									270.6	8.5	31.3
11.5				15.71	36.7	36.7	31.4	3.5	3.5	1.8						129.2	4.6	35.5
12				13.24	56.25	72.8	125.7	39.7	26.5						3.3	337.5	13.5	40.1
12.5					30.39	54.7	255.3	224.9	85.1	36.5	12.2		6.1	6.1	6.1	717.2	32.3	45.0
13					17.95	35.9	278.2	251.3	215.4	107.7	53.9	18.0	26.9	9.0	44.9	1059.1	53.4	50.4
13.5					10.25	30.74	256.2	225.4	215.2	143.5	61.48	51.2	41.0	20.5	112.7	1168.1	65.5	56.1
14							73.37	97.83	220.1	269	97.8	36.7	85.6	12.2	244.6	1137.3	70.8	62.3
14.5						11.72	11.72	23.44	35.17	93.77	11.72	70.33	70.33	70.33	351.7	750.2	51.6	68.8
15							13.34	13.34		26.69	26.69	26.69	66.71	26.69	253.5	453.7	34.4	75.8
15.5										24.97				24.97	237.2	287.2	23.9	83.3
16															138.6	138.6	12.6	91.2
16.5															48.47	48.5	4.8	99.7
17															20.9	20.9	2.3	108.6
17.5															2.66	2.7	0.3	118.0
18																		
18.5																		
19																		
19.5																		
20																		
SSN	-	-	1212	646	366.5	253.8	1057	879.4	800.9	703.8	263.7	202.9	296.6	169.8	1465	8,316.3	-	-
SSB	-	-	28.57	18.64	12.6	11.38	52.78	45.87	44.07	42.49	15.63	12.93	19.16	11.58	107.5	-	423.2	-
Mn wt (g)	-	17.1	22.9	28.7	34.1	44.8	50	52.2	55	60.4	59.3	63.7	64.6	68.2	73.4	-	-	-
Mn L (cm)	-	9.1	10.1	10.9	11.5	12.7	13.2	13.4	13.6	14.1	14	14.3	14.4	14.7	15	-	-	-

Table 5. Boarfish total biomass (000's tonnes) at age (years) by ICES statistical rectangle.

Region	Strata	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
North	42E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
	40E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	41E0	0	0	0	0	0	0	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.1	1.2	2.4
	41E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40E0	0	0	0	0	0	0	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.6	1.6
	40E1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.3
	39D9	0	0	0	0	0	0.1	0.5	0.5	0.6	0.8	0.3	0.2	0.3	0.2	2.2	5.7
	39E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2
	38D9	0	0	0	0	0	0	0.3	0.3	0.3	0.4	0.1	0.1	0.2	0.1	1.1	2.9
	37D9	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.2	0.7
Porc	36D6	0	0	0	0	0	0.1	0.5	0.5	0.7	1	0.3	0.3	0.5	0.4	3.9	8.2
	36D5	0	0	0	0	0	0.1	1	1.1	1.4	2	0.7	0.7	1.1	0.8	8	16.9
	35D5	0	0	0	0	0.1	0.2	1.6	1.6	2.1	3.1	1.1	1.1	1.8	1.2	13.1	26.9
	35D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2
	34D5	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	1.2	2
	34D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West	36D7	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0.4	1.2
	36D8	0	0	0	0	0.1	0.3	1.8	1.7	1.9	1.9	0.7	0.6	0.9	0.5	4.9	15.4
	36D9	0	0	0	0	0	0.1	0.5	0.5	0.5	0.5	0.2	0.2	0.3	0.2	1.6	4.6
	35D7	0	0	0	0	0	0.1	0.6	0.5	0.6	0.7	0.2	0.2	0.3	0.2	1.5	4.9
	35D8	0	0	0	0.1	0.2	0.4	2.4	2.4	2.6	2.8	1	0.8	1.2	0.7	6.5	21.1
	35D9	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.2	0.7
	34D7	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.5	1.5
	34D8	0	0	0	0.1	0.2	0.5	3.2	3	3	3.3	1.2	1.2	1.7	1.1	9.2	27.6
	34D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33D8	0	0	0.1	0.2	0.3	0.3	1.4	1.2	1.2	1.1	0.4	0.3	0.5	0.3	3.5	11
	33D9	0	0	0	0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.8	2.6
	32D8	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.6	2
	32D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
South	31D8	0	0	0.3	0.1	0.2	0.2	1.1	1	1	1	0.3	0.3	0.4	0.3	2.4	8.7
	31D9	0	0	0.1	0	0	0	0.2	0.1	0.1	0.1	0	0	0.1	0	0.3	1.3
	31E0	0	0	0.2	0.1	0.1	0.1	0.4	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.7	2.9
	30D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30D9	0	0	0.4	0.1	0.2	0.2	0.9	0.8	0.8	0.7	0.3	0.2	0.3	0.2	1.7	6.9
	30E0	0	0	0.5	0.3	0.2	0.2	0.7	0.6	0.5	0.4	0.1	0.1	0.2	0.1	0.7	4.4
	30E1	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0.1	0.3
	30E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29E1	0	0	1.3	0.8	0.6	0.5	1.9	1.6	1.3	1.1	0.4	0.3	0.4	0.2	1.9	12.4
	29E2	0	0	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0	0.4
	28D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28E0	0	0	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.1	0.9
	28E1	0	0.2	8.7	4.7	2.3	1.2	4.8	3.9	3.3	2.6	1	0.6	1	0.6	5.1	40
	28E2	0	0.4	13.2	6.6	2.4	0.3	1.1	0.9	0.7	0.6	0.2	0.1	0.2	0.2	1.7	28.4
	27D8	0	0	0.8	0.6	0.9	1.3	5.9	5.1	4.8	4.3	1.6	1.4	1.9	1.1	8.2	38
	27D9	0	0	0.1	0.1	0.1	0.2	0.8	0.7	0.7	0.6	0.2	0.2	0.3	0.2	1.1	5.2
	27E0	0	0	0.2	0.1	0.1	0.2	1	0.8	0.7	0.6	0.2	0.2	0.2	0.1	1	5.5
	27E1	0	0	0.1	0.1	0.2	0.2	1	0.8	0.7	0.5	0.2	0.1	0.2	0.1	0.8	4.9
	27E2	0	0.2	5.4	2.7	1	0.2	0.9	0.7	0.5	0.4	0.1	0.1	0.1	0.1	1	13.5
	26D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26E0	0	0	0.4	0.3	0.5	0.6	3.1	2.6	2.4	2	0.8	0.5	0.8	0.4	3.2	17.5
	26E1	0	0.1	2.1	0.5	0.7	0.8	3.2	2.6	2.2	1.8	0.7	0.5	0.7	0.4	3	19.4
	26E2	0	0.3	6	1.1	0.7	0.5	1	0.5	0.4	0.2	0.1	0	0	0	0.2	10.9
	25E0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25E1	0	0.1	1.2	0.4	0.7	1	4.3	3.6	3.1	2.6	1	0.7	1	0.6	4.2	24.5
	25E2	0	0	0.7	0.4	0.7	1	5.1	4.4	4	3.6	1.3	1	1.5	0.9	8.5	33.2
	24E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0	1.3	42.2	20	13	11.4	52.8	45.9	44.1	42.5	15.6	12.9	19.2	11.6	107.5	439.9
	%	0	0.3	9.6	4.6	3	2.6	12	10.4	10	9.7	3.6	2.9	4.4	2.6	24.4	100

Table 6. Boarfish total abundance (millions) at age (years) by ICES statistical rectangle.

Region	Strata	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
North	42E0	0.0	0.0	0.0	0.0	4.0	11.0	72.0	73.0	88.0	0.1	37.0	35.0	53.0	36.0	0.4	0.9
	40E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	41E0	0.0	0.0	0.0	17.0	0.2	0.4	2.8	2.8	3.4	4.2	1.4	1.4	2.0	1.4	14.8	34.9
	41E1	0.0	0.0	0.0	0.0	1.0	4.0	25.0	25.0	3.0	37.0	13.0	12.0	18.0	12.0	0.1	0.3
	40E0	0.0	0.0	0.0	24.0	0.2	0.4	2.5	2.4	3.0	3.4	1.1	1.0	1.5	0.8	7.9	24.3
	40E1	0.0	0.0	0.0	5.0	39.0	89.0	0.5	0.5	0.7	0.7	0.2	0.2	0.3	0.2	1.7	5.3
	39D9	0.0	0.0	0.0	88.0	0.6	1.5	8.9	8.7	10.8	12.1	4.1	3.7	5.2	3.0	28.5	87.2
	39E0	0.0	0.0	0.0	3.0	18.0	42.0	0.3	0.3	0.3	0.3	0.1	0.1	0.2	87.0	0.8	2.5
	38D9	0.0	0.0	0.0	45.0	0.3	0.8	4.6	4.5	5.5	6.2	2.1	1.9	2.7	1.6	14.7	44.9
	37D9	0.0	0.0	1.0	36.0	0.1	0.2	1.5	1.4	1.5	1.4	0.5	0.4	0.6	0.3	3.0	11.0
Porc	36D6	0.0	0.0	0.0	62.0	0.5	1.3	8.5	8.8	11.1	15.0	5.2	5.0	8.0	5.2	51.0	119.5
	36D5	0.0	0.0	0.0	0.1	1.0	2.6	17.4	18.0	22.6	30.6	10.7	10.3	16.4	10.6	104.3	244.6
	35D5	0.0	0.0	0.0	0.2	1.4	3.9	27.2	28.0	34.8	47.1	16.7	16.1	25.9	16.7	169.4	387.7
	35D6	0.0	0.0	0.0	2.0	12.0	33.0	0.2	0.2	0.3	0.4	0.1	0.1	0.2	0.1	1.4	3.2
	34D5	0.0	0.0	0.0	0.0	7.0	0.2	1.8	1.8	2.0	2.8	1.1	1.1	1.9	1.2	14.3	28.2
	34D6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	33D5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	33D6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Western	36D7	0.0	0.0	1.0	62.0	0.2	0.4	2.6	2.4	2.5	2.3	0.9	0.7	1.1	0.6	5.1	18.9
	36D8	0.0	0.0	18.0	0.8	3.0	5.5	34.6	31.8	32.9	30.8	12.0	9.3	13.9	7.3	67.1	249.0
	36D9	0.0	0.0	4.0	0.2	0.8	1.5	9.2	8.5	9.0	8.9	3.4	2.7	4.1	2.3	21.7	72.1
	35D7	0.0	0.0	73.0	1.0	1.1	1.6	10.6	1028.0	10.8	10.6	3.9	3.0	4.4	2.3	20.5	79.8
	35D8	0.0	0.0	0.3	3.8	4.6	7.0	45.7	43.3	46.3	45.5	16.9	12.9	19.0	9.8	88.8	343.9
	35D9	0.0	0.0	1.0	43.0	0.1	0.3	1.7	1.5	1.6	1.5	0.6	0.4	0.7	0.4	3.2	11.9
	34D7	0.0	0.0	2.0	82.0	0.3	0.6	3.2	2.9	2.8	2.8	1.0	1.0	1.4	0.8	6.7	23.6
	34D8	0.0	0.0	37.0	1.5	5.4	10.5	6077.0	55.1	53.6	52.8	19.4	18.5	25.7	15.7	125.3	443.8
	34D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	33D8	0.0	0.0	4.4	7.8	6.9	6.5	28.1	23.7	21.9	19.0	7.2	5.4	7.9	4.4	45.1	188.2
	33D9	0.0	0.0	1.0	1.8	1.6	1.5	6.6	5.6	5.1	4.5	1.7	1.3	1.9	1.0	10.6	44.3
	32D8	0.0	0.0	0.5	0.1	0.6	1.0	4.7	4.2	4.1	3.9	1.4	1.2	1.6	1.1	8.4	32.7
	32D9	0.0	0.0	15.0	4.0	19.0	32.0	0.2	0.1	0.1	0.1	45.0	4.0	53.0	35.0	0.3	1.1
South	31D8	0.0	0.6	15.4	4.0	4.7	5.5	22.4	18.9	17.7	15.8	5.7	4.8	6.5	3.9	32.4	158.3
	31D9	0.0	0.1	3.3	0.9	0.9	0.9	3.5	2.9	2.6	2.3	0.8	0.7	0.9	0.5	4.5	24.8
	31E0	0.0	0.3	7.6	2.0	2.0	2.1	8.0	6.5	6.0	5.2	1.9	1.5	2.1	1.2	10.2	56.5
	30D8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	30D9	0.0	0.7	17.7	4.6	4.6	4.8	18.6	15.3	14.0	12.0	4.4	3.6	4.9	2.8	23.8	131.8
	30E0	0.0	0.2	19.9	9.7	5.9	4.1	14.5	11.2	9.0	6.7	2.6	1.6	2.4	1.2	1074.0	99.3
	30E1	0.0	18.0	1.5	0.8	0.5	0.3	1.1	0.9	0.7	0.5	0.2	0.1	0.2	91.0	0.8	7.6
	30E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	29D8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	29D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	29E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	29E1	0.0	0.7	57.9	28.4	17.0	11.5	40.5	31.3	25.0	18.4	7.2	4.2	6.6	3.3	27.5	279.4
	29E2	0.0	0.3	7.3	3.0	1.0	99.0	0.3	0.2	0.2	0.1	42.0	26.0	33.0	28.0	0.3	13.0
	28D8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	28D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	28E0	0.0	49.0	4.2	2.1	1.3	0.9	3.0	2.3	1.9	1.4	0.5	0.3	0.5	0.2	2.1	20.7
	28E1	0.0	11.8	376.1	164.5	73.3	29.1	101.1	77.6	61.6	45.2	17.6	10.4	16.0	8.4	70.8	1063.4
	28E2	0.0	23.5	573.0	234.8	82.0	7.8	24.1	17.6	12.8	9.5	3.3	2.0	2.6	2.2	21.5	1016.8
	27D8	0.0	0.0	31.8	20.6	24.0	28.6	118.6	97.8	88.1	72.6	27.1	22.3	30.2	17.0	119.5	698.2
	27D9	0.0	0.0	4.4	2.8	3.3	3.9	16.4	13.5	12.2	1011.0	3.7	3.1	4.2	2.3	16.5	96.3
	27E0	0.0	0.0	7.0	4.0	3.9	4.3	19.2	15.9	13.6	10.5	4.1	2.7	3.8	1.8	14.4	105.3
	27E1	0.0	0.2	3.0	3.5	4.7	5.7	21.4	16.4	12.7	8.1	3.4	1.9	2.9	1.3	11.1	96.3
	27E2	0.0	9.6	234.7	97.1	35.3	5.4	18.2	13.6	10.2	7.0	2.7	1.6	2.2	1.4	13.1	452.2
	26D9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	26E0	0.0	0.0	18.6	11.5	12.3	14.3	62.1	51.1	43.8	33.5	13.2	8.7	12.3	5.9	46.3	333.6
	26E1	0.0	6.6	96.5	18.0	17.8	18.7	66.5	51.7	42.3	31.2	12.0	7.9	11.3	6.1	43.6	430.2
	26E2	0.0	18.5	269.4	38.8	20.7	11.5	22.6	11.8	7.6	3.2	1.2	0.7	0.9	0.6	2.6	410.2
	25E0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	25E1	0.0	3.8	55.5	13.7	19.1	23.3	88.7	70.7	58.7	44.0	16.9	11.1	16.1	8.6	62.2	492.5
	25E2	0.0	0.9	31.7	13.9	18.4	23.0	102.1	85.5	73.5	59.9	22.9	15.9	23.3	13.7	116.3	601.0
	24E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	24E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	0.0	78.0	1842.9	696.4	381.6	253.8	1056.6	879.4	800.9	703.8	263.7	202.9	296.6	169.8	1464.5	9091.0
	%	0.0	0.9	20.3	7.7	4.2	2.8	11.6	9.7	8.8	7.7	2.9	2.2	3.3	1.9	16.1	100.0
	Cv (%)	NA	41.0	36.4	37.1	25.1	18.7	17.8	17.8	17.8	17.8	17.8	17.8	17.8	18.8	18.8	NA

Table 7. Boarfish biomass (000's tonnes) by maturity by ICES statistical rectangle.

Region	Strata	Imm	Mature	Spent	Total
North	42E0	0	0.1	0	0.1
	40E0	0	0	0	0
	41E0	0	2.4	0	2.4
	41E1	0	0	0	0
	40E0	0	1.6	0	1.6
	40E1	0	0.3	0	0.3
	39D9	0	5.7	0	5.7
	39E0	0	0.2	0	0.2
	38D9	0	2.9	0	2.9
	37D9	0	0.7	0	0.7
Porc	36D6	0	8.2	0	8.2
	36D5	0	16.9	0	16.9
	35D5	0	26.9	0	26.9
	35D6	0	0.2	0	0.2
	34D5	0	2	0	2
	34D6	0	0	0	0
	33D5	0	0	0	0
	33D6	0	0	0	0
West	36D7	0	1.2	0	1.2
	36D8	0	15.4	0	15.4
	36D9	0	4.6	0	4.6
	35D7	0	4.9	0	4.9
	35D8	0	21.1	0	21.1
	35D9	0	0.7	0	0.7
	34D7	0	1.5	0	1.5
	34D8	0	27.6	0	27.6
	34D9	0	0	0	0
	33D8	0	10.9	0	11
	33D9	0	2.6	0	2.6
	32D8	0	2	0	2
	32D9	0	0.1	0	0.1
South	31D8	0.1	8.5	0	8.7
	31D9	0	1.3	0	1.3
	31E0	0.1	2.9	0	2.9
	30D8	0	0	0	0
	30D9	0.2	6.7	0	6.9
	30E0	0.2	4.3	0	4.4
	30E1	0	0.3	0	0.3
	30E2	0	0	0	0
	29D8	0	0	0	0
	29D9	0	0	0	0
	29E0	0	0	0	0
	29E1	0.5	11.9	0	12.4
	29E2	0.1	0.3	0	0.4
	28D8	0	0	0	0
	28D9	0	0	0	0
	28E0	0	0.9	0	0.9
	28E1	3.2	36.7	0	40
	28E2	5.1	23.3	0	28.4
	27D8	0.2	37.8	0	38
	27D9	0	5.2	0	5.2
	27E0	0.1	5.4	0	5.5
	27E1	0	4.9	0	4.9
	27E2	2.1	11.4	0	13.5
	26D9	0	0	0	0
	26E0	0.2	17.3	0	17.5
	26E1	1	18.3	0	19.4
	26E2	2.8	8.1	0	10.9
	25E0	0	0	0	0
	25E1	0.6	23.9	0	24.5
	25E2	0.3	33	0	33.2
	24E2	0	0	0	0
	24E3	0	0	0	0
	Total	16.7	423.2	0	439.9
	%	3.8	96.2	0	100

Table 8. Boarfish abundance (millions) by maturity by ICES statistical rectangle.

Region	Strata	Imm	Mature	Spent	Total
North	42E0	0	0.9	0	0.9
	40E0	0	0	0	0
	41E0	0	34.9	0	34.9
	41E1	0	0.3	0	0.3
	40E0	0	24.3	0	24.3
	40E1	0	5.3	0	5.3
	39D9	0	87.2	0	87.2
	39E0	0	2.5	0	2.5
	38D9	0	44.9	0	44.9
	37D9	0	11.0	0	11.0
Porc	36D6	0	119.5	0	119.5
	36D5	0	244.6	0	244.6
	35D5	0	387.7	0	387.7
	35D6	0	3.2	0	3.2
	34D5	0	28.2	0	28.2
	34D6	0	0	0	0
	33D5	0	0	0	0
	33D6	0	0	0	0
West	36D7	0	18.9	0	18.9
	36D8	0	249.0	0	249.0
	36D9	0	72.1	0	72.1
	35D7	0.0	79.8	0	79.8
	35D8	0.1	343.7	0	343.9
	35D9	0	11.9	0	11.9
	34D7	0	23.6	0	23.6
	34D8	0	443.8	0	443.8
	34D9	0	0	0	0
	33D8	1.3	187.0	0	188.2
	33D9	0.3	44.0	0	44.3
	32D8	0.1	32.6	0	32.7
	32D9	0.0	1.1	0	1.1
South	31D8	6.3	152.0	0	158.3
	31D9	1.4	23.4	0	24.8
	31E0	3.2	53.3	0	56.5
	30D8	0	0	0	0
	30D9	7.5	124.3	0	131.8
	30E0	7.1	92.2	0	99.3
	30E1	0.5	7.1	0	7.6
	30E2	0	0	0	0
	29D8	0	0	0	0
	29D9	0	0	0	0
	29E0	0	0	0	0
	29E1	20.7	258.8	0	279.4
	29E2	3.0	10.0	0	13.0
	28D8	0	0	0	0
	28D9	0	0	0	0
	28E0	1.5	19.2	0	20.7
	28E1	146.5	916.8	0	1063.4
	28E2	233.1	783.7	0	1016.8
	27D8	8.2	690.0	0	698.2
	27D9	1.1	95.2	0	96.3
	27E0	2.9	102.4	0	105.3
	27E1	1.2	95.1	0	96.3
	27E2	95.5	356.7	0	452.2
	26D9	0	0	0	0
	26E0	7.7	326.0	0	333.6
	26E1	48.8	381.4	0	430.2
	26E2	136.1	274.0	0	410.2
	25E0	0	0	0	0
	25E1	28.1	464.3	0	492.5
	25E2	12.5	588.5	0	601.0
	24E2	0	0	0	0
	24E3	0	0	0	0
	Total	8316.3	8316.3	0	9,091
	%	91.5	91.5	0.0	100

Table 9. Boarfish biomass and abundance by ICES statistical rectangle.

Region	Stratum	No. transects	No. schools	Def schools	Prob schools	Mix schools	% zeros	Def Biomass	Prob Biomass	Mix Biomass	Biomass (000't)	SSB (000't)	Abundance millions
North	42E0	4	5	1	0	4	75	0	0	0	0.1	0.1	0.9
	40E0	3	0	0	0	0	100	0	0	0	0	0	0.0
	41E0	4	18	18	0	0	0	2.4	0	0	2.4	2.4	34.9
	41E1	4	1	1	0	0	75	0	0	0	0	0	0.3
	40E0	4	24	13	0	11	25	0.8	0	0.8	1.6	1.6	24.3
	40E1	4	7	0	0	7	75	0	0	0.3	0.3	0.3	5.3
	39D9	1	4	4	0	0	0	5.7	0	0	5.7	5.7	87.2
	39E0	4	3	3	0	0	50	0.2	0	0	0.2	0.2	2.5
	38D9	2	9	9	0	0	0	2.9	0	0	2.9	2.9	44.9
	37D9	2	5	5	0	0	50	0.7	0	0	0.7	0.7	11.0
Porc	36D6	1	15	15	0	0	0	8.2	0	0	8.2	8.2	119.5
	36D5	1	7	7	0	0	0	16.9	0	0	16.9	16.9	244.6
	35D5	2	28	28	0	0	0	26.9	0	0	26.9	26.9	387.7
	35D6	2	2	2	0	0	50	0.2	0	0	0.2	0.2	3.2
	34D5	2	9	9	0	0	50	2	0	0	2	2	28.2
	34D6	2	0	0	0	0	100	0	0	0	0	0	0.0
	33D5	1	0	0	0	0	100	0	0	0	0	0	0.0
	33D6	1	0	0	0	0	100	0	0	0	0	0	0.0
West	36D7	1	5	5	0	0	0	1.2	0	0	1.2	1.2	18.9
	36D8	3	41	41	0	0	0	15.4	0	0	15.4	15.4	249.0
	36D9	3	31	31	0	0	0	4.6	0	0	4.6	4.6	72.1
	35D7	2	15	15	0	0	0	4.9	0	0	4.9	4.9	79.8
	35D8	2	55	55	0	0	0	21.1	0	0	21.1	21.1	343.9
	35D9	2	12	12	0	0	0	0.7	0	0	0.7	0.7	11.9
	34D7	2	10	9	1	0	0	0.6	0.8	0	1.5	1.5	23.6
	34D8	2	105	105	0	0	0	27.6	0	0	27.6	27.6	443.8
	34D9	2	0	0	0	0	100	0	0	0	0	0	0.0
	33D8	2	38	38	0	0	0	11	0	0	11	10.9	188.2
	33D9	2	2	2	0	0	50	2.6	0	0	2.6	2.6	44.3
	32D8	2	15	15	0	0	50	2	0	0	2	2	32.7
	32D9	2	2	2	0	0	50	0.1	0	0	0.1	0.1	1.1
South	31D8	2	31	31	0	0	0	8.7	0	0	8.7	8.5	158.3
	31D9	2	10	10	0	0	0	1.3	0	0	1.3	1.3	24.8
	31E0	2	12	12	0	0	0	3	0	0	3	2.9	56.5
	30D8	1	0	0	0	0	100	0	0	0	0	0	0.0
	30D9	2	16	16	0	0	50	6.9	0	0	6.9	6.7	131.8
	30E0	2	14	14	0	0	50	4.4	0	0	4.4	4.3	99.3
	30E1	2	7	7	0	0	50	0.3	0	0	0.3	0.3	7.6
	30E2	2	0	0	0	0	100	0	0	0	0	0	0.0
	29D8	2	0	0	0	0	100	0	0	0	0	0	0.0
	29D9	2	0	0	0	0	100	0	0	0	0	0	0.0
	29E0	2	0	0	0	0	100	0	0	0	0	0	0.0
	29E1	2	16	16	0	0	50	12.4	0	0	12.4	11.9	279.4
	29E2	2	2	2	0	0	50	0.4	0	0	0.4	0.3	13.0
	28D8	2	0	0	0	0	100	0	0	0	0	0	0.0
	28D9	2	0	0	0	0	100	0	0	0	0	0	0.0
	28E0	2	3	3	0	0	50	0.9	0	0	0.9	0.9	20.7
	28E1	2	90	90	0	0	0	40	0	0	40	36.7	1063.4
	28E2	2	12	12	0	0	50	28.4	0	0	28.4	23.3	1016.8
	27D8	2	25	25	0	0	50	38	0	0	38	37.8	698.2
	27D9	2	17	15	2	0	0	5.1	0.2	0	5.2	5.2	96.3
	27E0	2	12	12	0	0	50	5.5	0	0	5.5	5.4	105.3
	27E1	2	24	15	9	0	50	4.7	0.2	0	4.9	4.9	96.3
	27E2	2	46	39	7	0	0	10.3	3.2	0	13.5	11.4	452.2
	26D9	1	0	0	0	0	100	0	0	0	0	0	0.0
	26E0	2	64	64	0	0	0	17.5	0	0	17.5	17.3	333.6
	26E1	2	64	64	0	0	0	19.4	0	0	19.4	18.3	430.2
	26E2	2	35	35	0	0	0	10.9	0	0	10.9	8.1	410.2
	25E0	1	0	0	0	0	100	0	0	0	0	0	0.0
	25E1	2	34	30	4	0	50	22.3	2.2	0	24.5	23.9	492.5
	25E2	2	72	70	2	0	0	32.7	0.5	0	33.2	33	601.0
	24E2	1	0	0	0	0	100	0	0	0	0	0	0.0
	24E3	2	0	0	0	0	100	0	0	0	0	0	0.0
	Total	131	1074	1027	25	22	43	431.6	7.2	1.1	440	423.2	9,091.0
	Cv (%)	-	-	-	-	-	-	-	-	-	16.7	NA	17.5

Table 10. Boarfish survey time series. Updated with new TS-Length relationship.

Age (Yrs)	2011	2012	2013
0	-	-	-
1	4.9	21.5	-
2	11.3	10.8	78.0
3	54.2	174.1	1,842.9
4	176.0	64.8	696.4
5	404.7	95.0	381.6
6	1,068.0	736.1	253.8
7	1,052.0	973.8	1,056.6
8	632.5	758.9	879.4
9	946.1	848.6	800.9
10	831.8	955.9	703.8
11	259.7	650.9	263.7
12	457.2	1,099.7	202.9
13	281.7	857.2	296.6
14	257.2	655.8	169.8
15+	1,746.0	6,353.7	1,464.3
TSN (mil)	8,183	14,257	9,091
TSB ('000t)	456,115	863,446	439,890
SSB ('000t)	455,375	861,544	423,158
CV	17.5	10.6	17.5

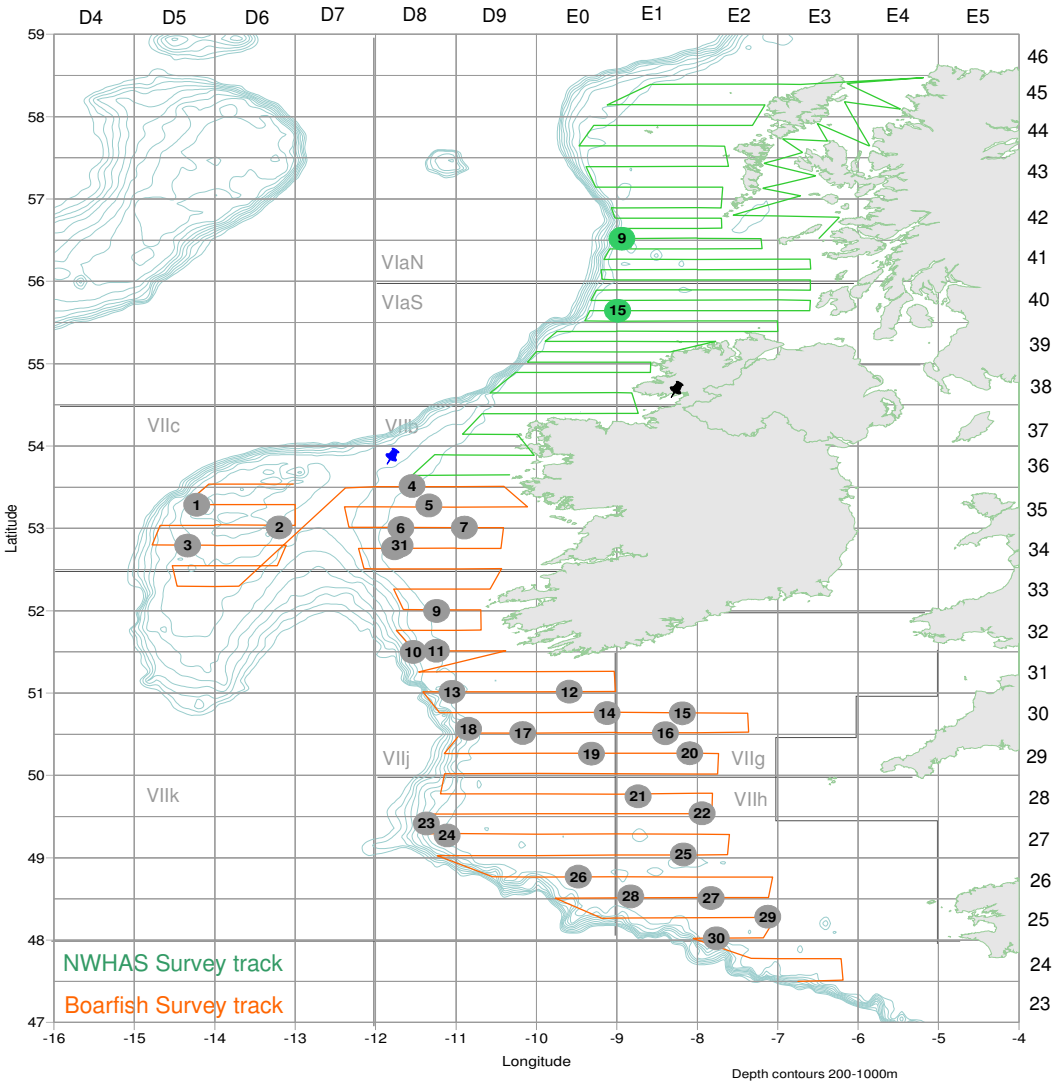


Figure 1. Cruise tracks and haul positions for the FV *Felucca* (orange) and RV *Celtic Explorer* (green). Note: hauls containing boarfish only. Black pin represent *Felucca* calibration site, blue pin Intercalibration site.

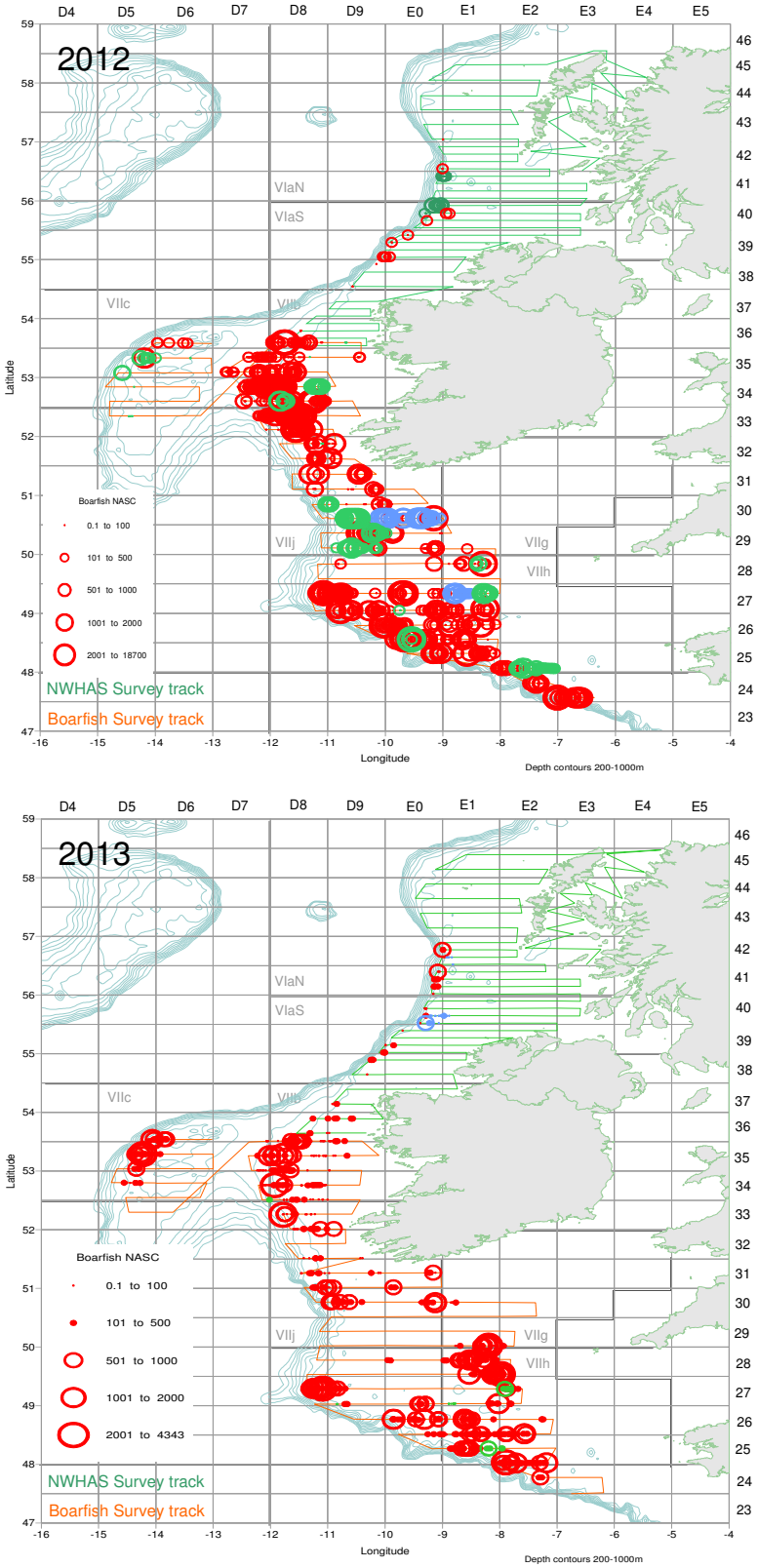


Figure 2. NASC plot of boarfish distribution Top panel 2012 and bottom panel 2013. Note: Circle size proportional to NASC value. Red circles represent 'definitely' boarfish, green; 'probably boarfish', blue; 'boarfish in a mix'.

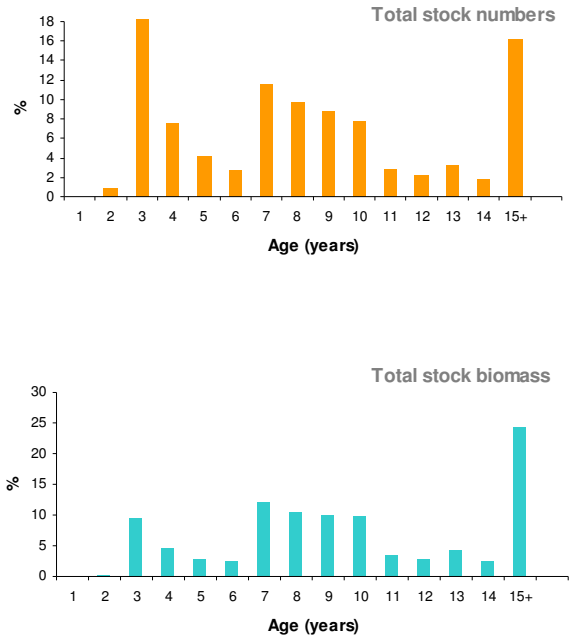
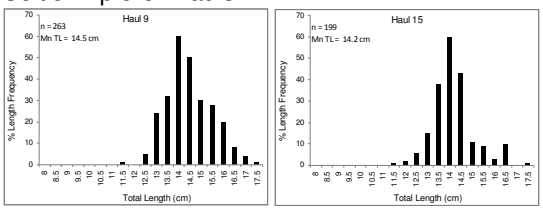


Figure 3. Percentage breakdown of total stock numbers (top) and total stock biomass (bottom) of survey stock.

Celtic Explorer Hauls



Felucca Hauls

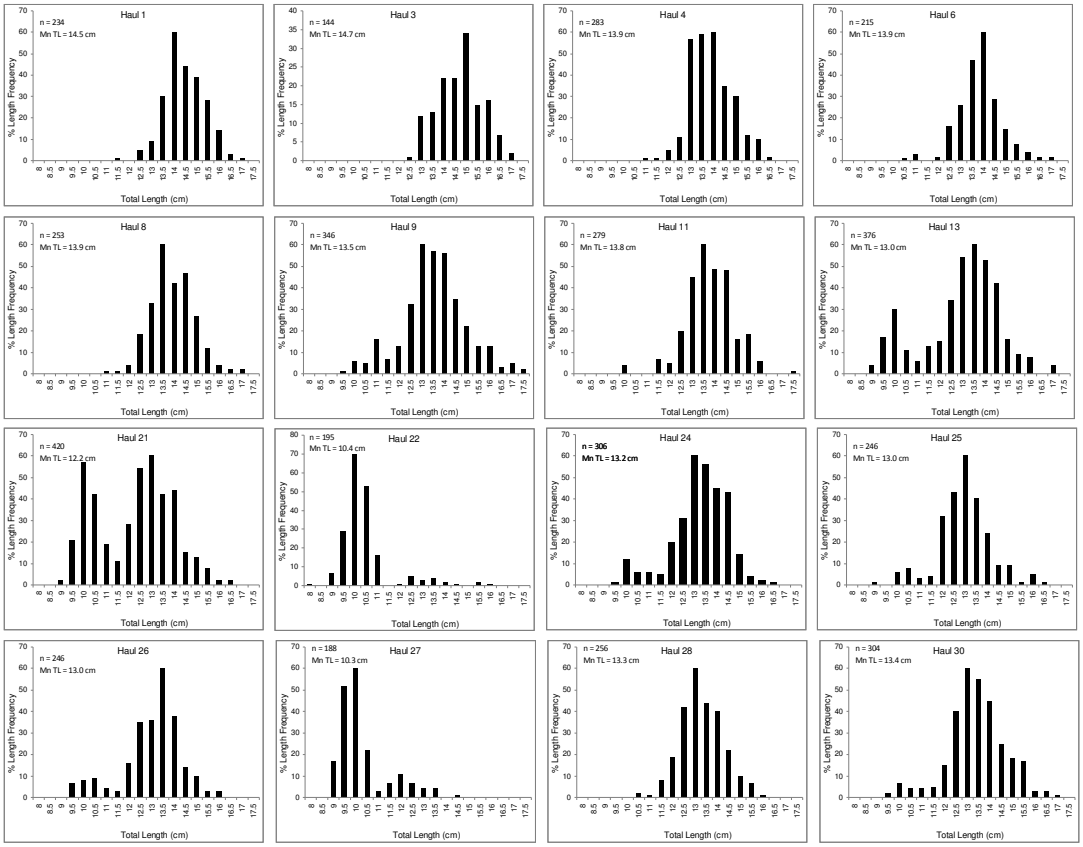
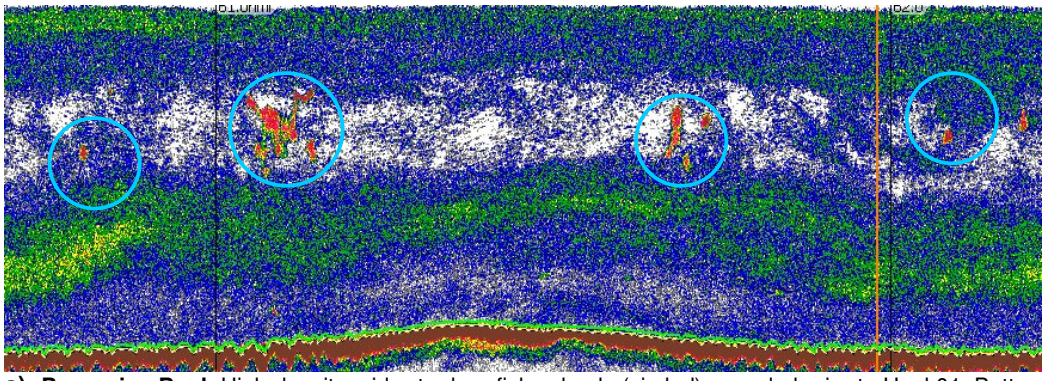
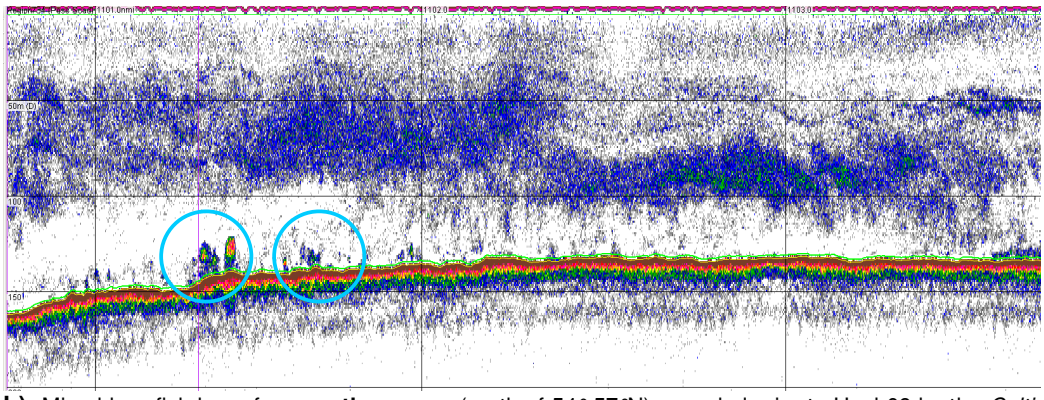


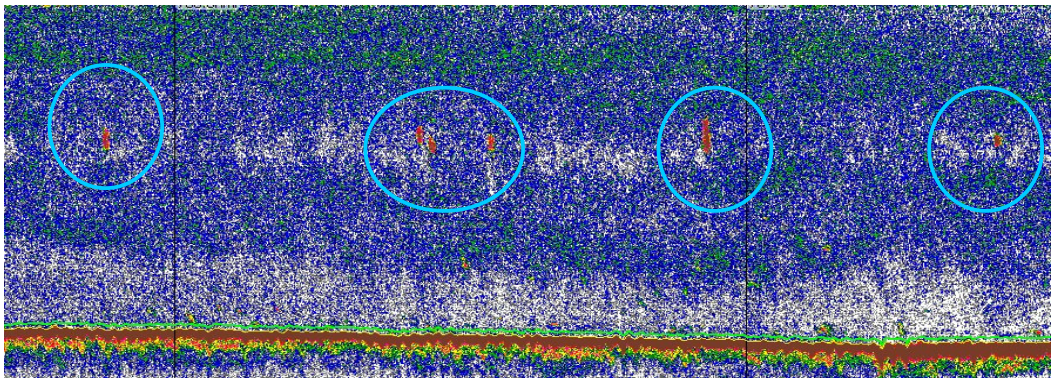
Figure 4. Mean length and length distribution of boarfish by haul.



a). Porcupine Bank High density midwater boarfish schools (circled) recorded prior to Haul 01. Bottom depth is 235m with targets occurring at 150m.

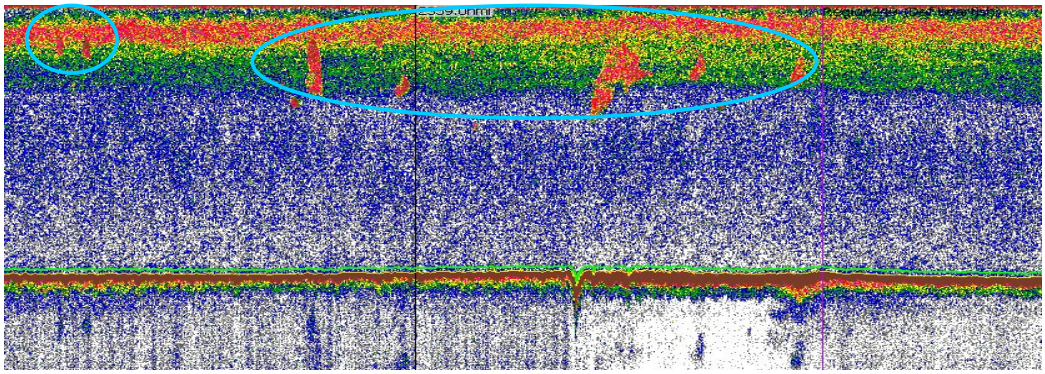


b). Mixed boarfish layer from **northern area** (north of 54°-57°N) recorded prior to Haul 09 by the *Celtic Explorer*. Bottom depth is 145m with targets at 0-18m. Haul contained: boarfish (18%), mackerel (31%) and herring (51%).

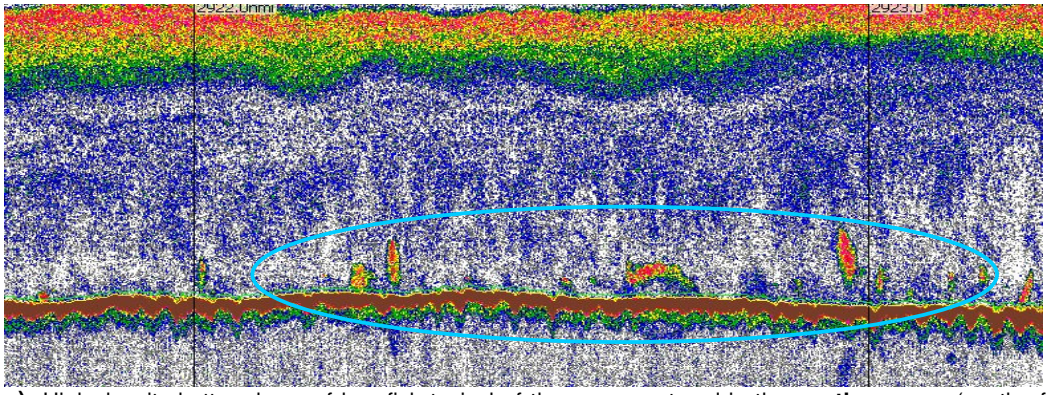


c). Medium-density midwater boarfish schools (circled) typical of those encountered in the **western area** (51°-54°N) Haul 06. Bottom depth is 160m with target schools at 60m.

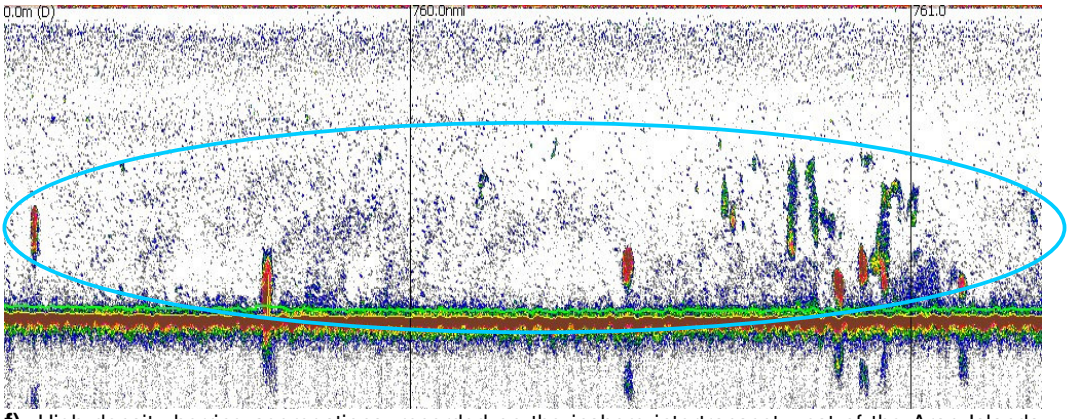
Figures 5a-h. Echotraces recorded on 38 kHz. Note: vertical bands on echograms represent 1nmi (nautical mile) sampling intervals.



d). High density surface feeding aggregations of boarfish recorded prior to Haul 22, located on-shelf in the **southern area**. Boarfish schools were located below or within the red surface plankton layer. Maturity analysis showed schools composed primarily of pre-recuit and resting mature boarfish. Bottom depth is 144m with targets extending from 20-65m depth.

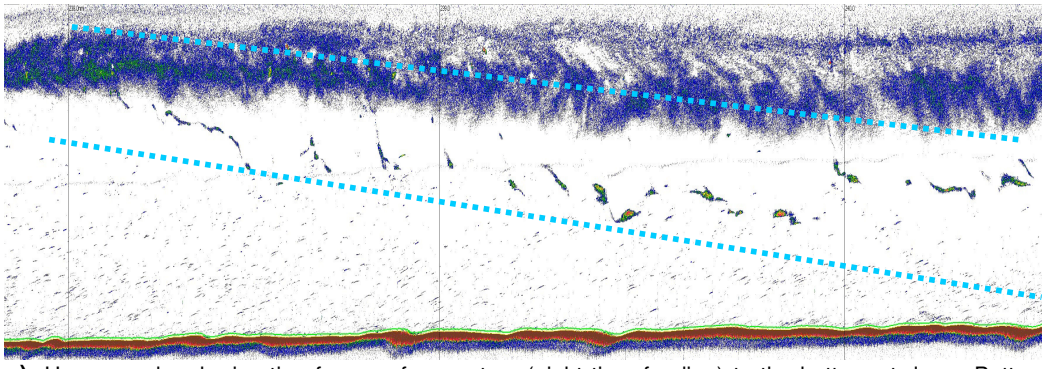


e). High density bottom layer of boarfish typical of those encountered in the **southern area** (south of 50°N). Echogram recorded prior to Haul 26. Bottom depth is 170m with targets extending from 0-40m off the bottom.

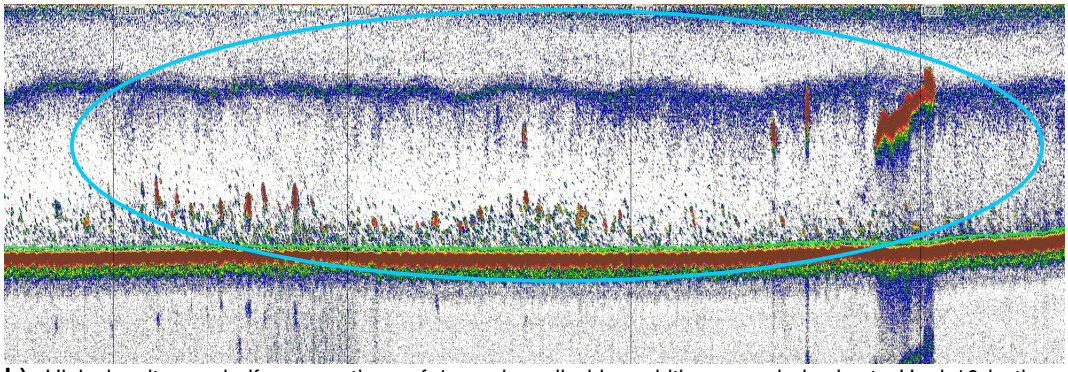


f). High density herring aggregations, recorded on the inshore intertransect west of the Aran Islands. Bottom depth is 80m with targets extending from 0-40m off the bottom.

Figures 5a-h. continued.



g). Horse mackerel migrating from surface waters (night time feeding) to the bottom at dawn. Bottom depth is 220m, echogram extends c.3nmi, recorded in the western area.



h). High-density on-shelf aggregations of 1year juvenile blue whiting recorded prior to Haul 16 in the southern region. Mark intensity and size typical of those encountered south of 51°N. Note: echogram extends c.4nmi.

Figures 5a-h. continued.

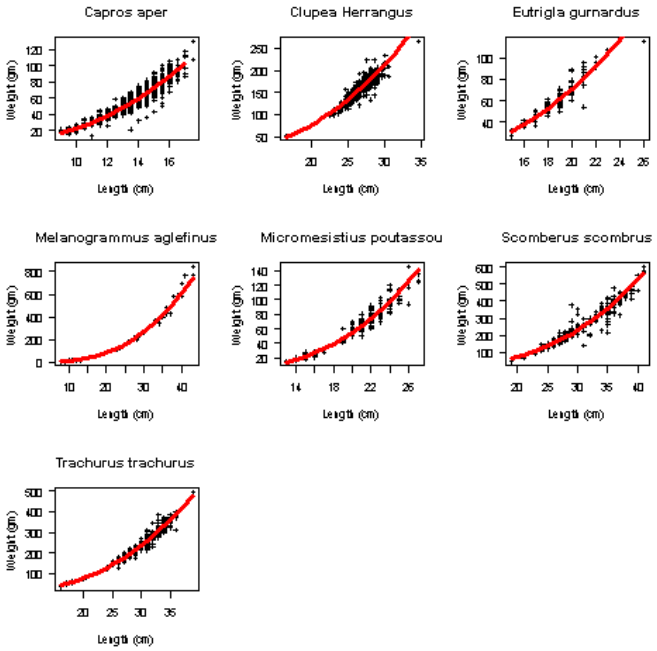


Figure 6. Length weight plots of major trawl component species used during the analysis.

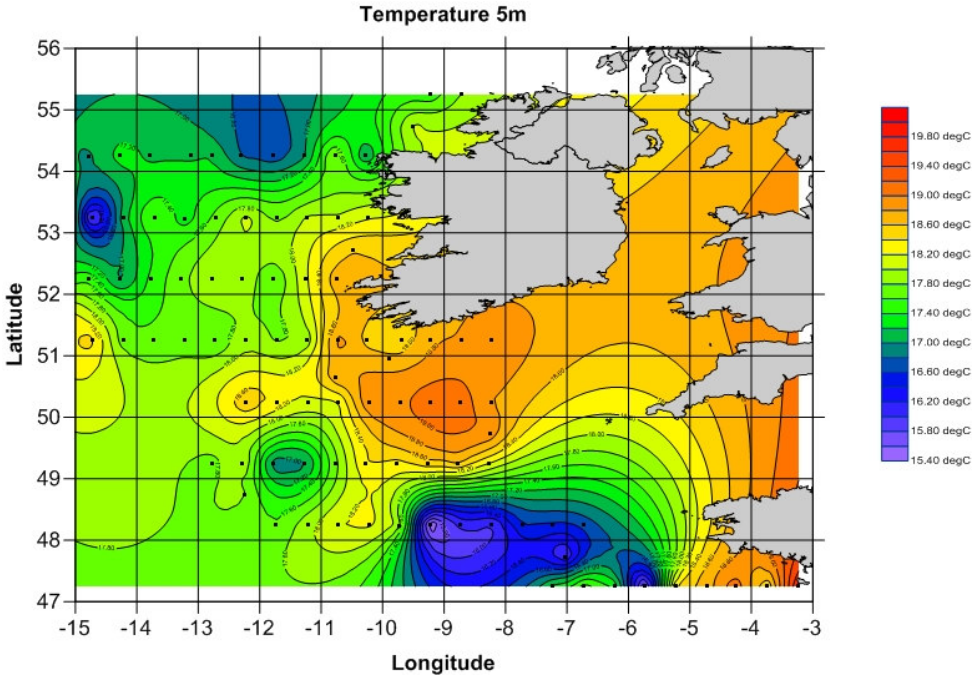


Figure 7. Sea surface temperature (5m). Black dots represent location of CTD cast (n=97).

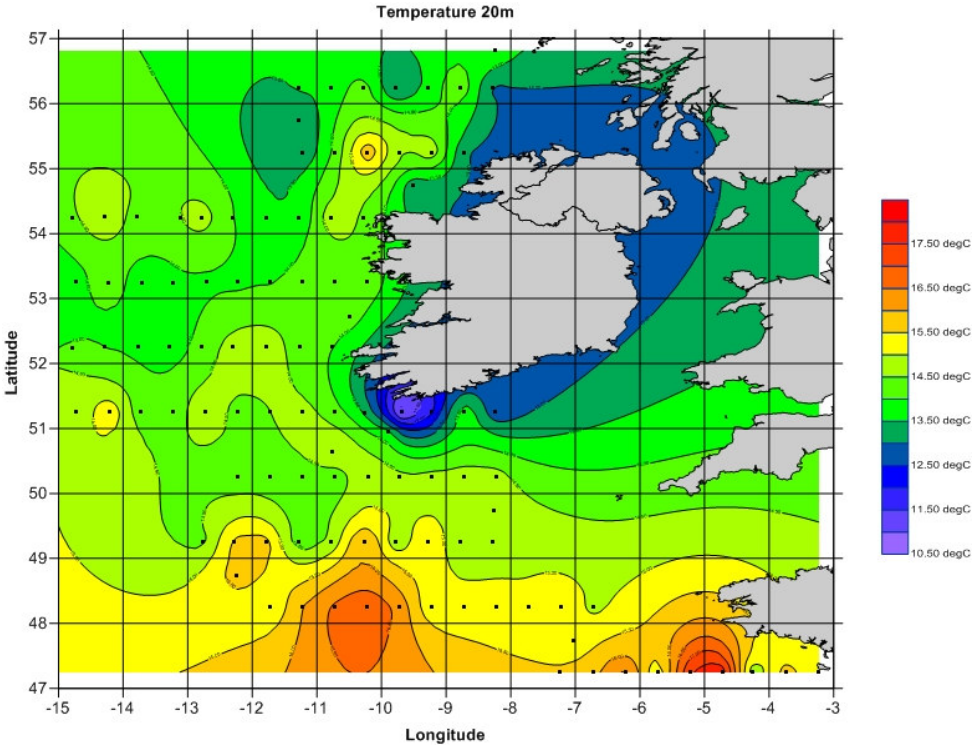


Figure 8. Temperature profile at 20m. Black dots represent location of CTD cast (n=97).

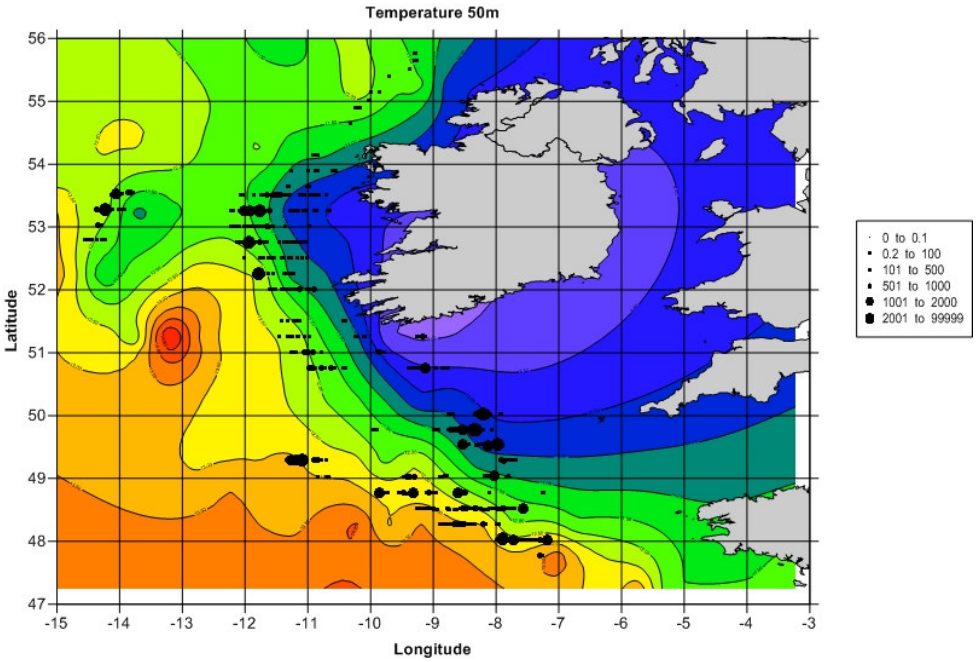


Figure 9. Boarfish NASC with temperature profile at 50m.

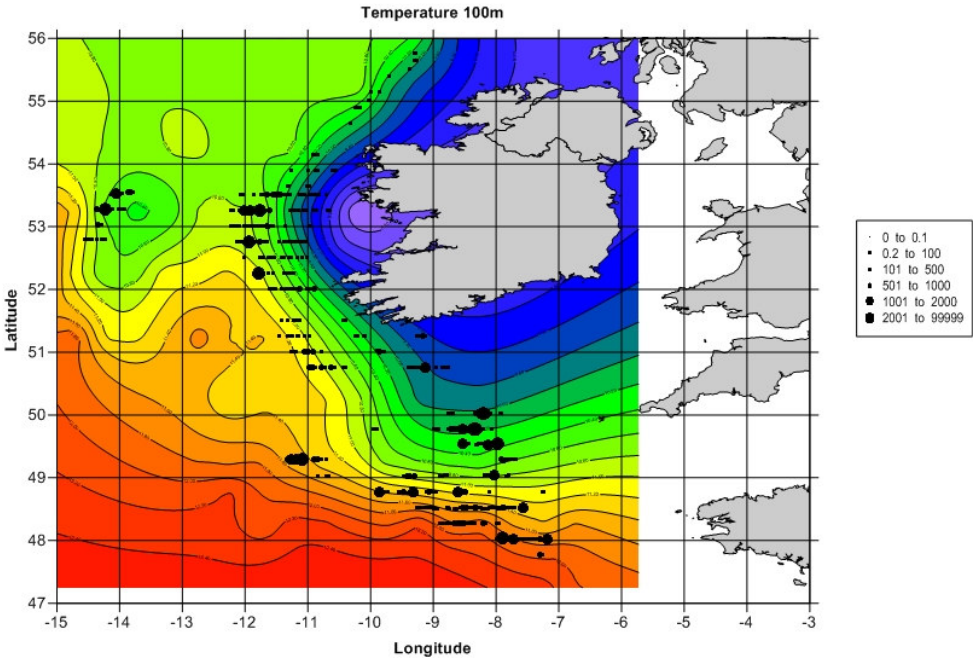


Figure 10. Boarfish NASC with temperature profile at 100m

Appendix 1

Details of the charter vessel and tow body set up used during the survey.

Figure 1. FV *Felucca* (SO 108). 54m LOA

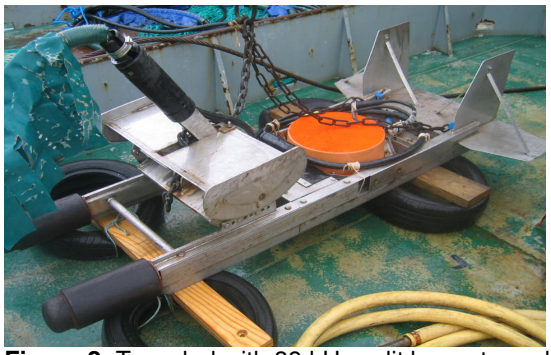


Figure 2. Tow sled with 38 kHz split beam transducer (orange centre screen).

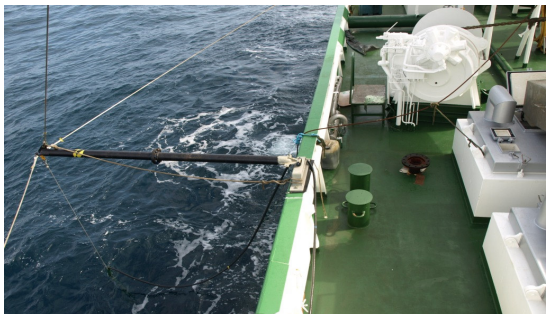


Figure 3. Towing boom c.3m long, with support stays.

Figure 4. Top side monitoring station located on the bridge. Laptop (left) running Echoview and EK60 topside PC unit (right).